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ABSTRACT

The purpose of this study was to determine whether relationships occur among spatial skills, logical reasoning, and various genetic concepts. Twenty-one students enrolled in an undergraduate genetics course in a northern New Jersey institution completed a series of tests and tasks designed to measure flexibility of closure, visualization, proportional schemata, induction, propositional logic, and understanding of genetics concepts. Results showed that certain genetics topics are strongly associated with visualization skills, proportional schemata, induction, and disjunctive reasoning. It may be inferred that mitosis, meiosis, the trihybrid test cross, and four other concepts have something in common with each other that is not measured by the tests and tasks for visualization, logical thinking, flexibility of closure, and scheme of proportionality. Interestingly, the Hidden Patterns Test and items concerning map units have something in common and load heavily in a factor. Data from this study should be interpreted with caution, as the sample size was small and the variables were both continuous and dichotomous in nature. This information may provide criteria useful to teachers selecting or writing programs for their genetics courses or for biology teachers preparing genetics units. (Author/JN)

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The Relationships Among Logical and Spatial Skills and Understanding Genetics Concepts and Problems

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ABSTRACT

The purpose of this study was to determine whether relationships occur among spatial skills, logical reasoning, and various genetics concepts. The design included twenty-one students enrolled in basic undergraduate genetics courses in northern New Jersey institutions. These students completed a series of tests and tasks designed to measure flexibility of closure, visualization, proportional schemata, induction, propositional logic, and understanding of genetics concepts.

Preliminary correlations and factor analyses showed that certain topics in genetics are strongly associated with visualization skills, proportional schemata, induction, and disjunctive reasoning. It may be inferred that the cluster of genetics items concerning the number of gamete genotypes, mitosis, meiosis (from gametes to diploid cell), calculating gene frequency, the trihybrid test cross, the pedigree, and the relationship between a DNA sequence and its complimentary mRNA sequence have something in common with each other that is not measured by the tests and tasks for visualization, logical reasoning, flexibility of closure, and scheme of proportionality used in this study. Interestingly, the Hidden Patterns Test and items concerning map units have something in common and load heavily in a factor. The data from this study was interpreted with caution, as the sample size was small and the variables were both continuous and dichotomous in nature.

Further research concerning these relations and possibly others is recommended in light of the increased use of microcomputers as instructional devices in biology classrooms. This information may provide criteria that could be useful to teachers selecting or writing programs for their genetics courses or for biology teachers preparing genetics units.

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THE RELATIONSHIPS AMONG LOGICAL AND SPATIAL SKILLS AND UNDERSTANDING GENETICS CONCEPTS AND PROBLEMS

INTRODUCTION

The inference that many college students remain at the level of concrete operational thought because of the lack of reinforcing experiences in reasoning at the formal level is unfortunate (Walker, Hendrix, and Mertens, 1980). It is certainly disheartening to see college students unable to apply critical analyses to complex data; i.e., genetics analysis. Walker, Hendrix, and Mertens (1979) have demonstrated that organized early instruction in introductory genetics can guide the student step-by-step through the application of Piagetian formal operations to genetic data.

Others such as Douglass (1978, 1979) and Charlton (1980) have been concerned with cognitive style and genetics sequenced instruction, but their findings are significant only for subjects at the extremes of the distribution. Yearney, Helseth, and Barstow (1980) show that subjects in their study who were "formal and internal" scored higher on the genetics measure than subjects who were "formal and external". However, there was no correlation between locus of control and cognitive development.

In addition to the problem of insufficient data concerning the logical and spatial skills necessary for understanding genetics concepts, Mertens (1971) complicates the matter by questioning whether Mendel or meiosis should be taught first. Mertens argues that a cytological basis is necessary and easier to grasp than probability and mathematical theory.

The main purpose of the current study was to determine the cognitive and spatial requirements necessary for understanding genetics concepts and problems. The second purpose was to determine if there were any relationships between these requirements with respect to subject matter. Since the area concerning spatial skills has received little attention with respect to understanding genetics concepts, an exploratory approach was taken to provide a foundation for future research.

It is hoped that the current study and future studies will provide information for developing instructional strategies for introductory genetics courses that are compatible with cognitive development and acquisition of spatial skills. Further research may then be employed to assess the effects of such instruction on the development of cognitive and spatial skills. Perhaps a more realistic view of students' abilities coupled with an appropriate instructional strategy would alleviate students' anxieties over genetics problems and provide both students and teachers with more rewarding experiences.

SUBJECTS

A sample of 21 students, 5 females and 16 males, who were enrolled in a basic undergraduate genetics course volunteered for the current study. The descriptive statistics for this sample may be found in Table 1.

TABLE 1

SUMMARY OF DESCRIPTIVE STATISTICS

Variables	n	Mean	Standard Deviation	Minimum	Maximum
Sex (female=0, male=1)	21	0.76	0.44	0.00	1.00
Age	*20	259.45	22.43	244.00	348.00
Status (sophomore=2, junior=3, senior=4)	21	3.24	0.54	2.00	4.00
Years of mathematics	*20	4.48	1.08	2.00	6.00
Hidden Patterns Test Score	21	177.40	70.56	59.00	286.00
Paper Folding Test Score	21	6.67	5.78	-4.00	14.00
Figure Classification Test Score	21	79.14	34.00	27.00	138.00
Surface Development Test Score	21	20.62	23.74	-22.00	58.00
Recipe Score	21	0.86	0.36	0.00	1.00
Mr. Tall-Mr. Short Score	21	0.71	0.46	0.00	1.00
PLT-conjunction score	21	3.48	1.08	0.00	4.00
PLT-conditional score	21	2.10	1.84	0.00	4.00
PLT-biconditional score	21	1.86	1.53	0.00	4.00
PLT-disjunction (inclusive) score	21	2.43	1.29	0.00	4.00

METHOD

The subjects were asked to complete a series of tests and tasks. The order in which these were given and the aspects which were measured are as follows.

1.	Hidden Patterns Test	Flexibility of closure
2.	Paper Folding Test	Visualization
3.	Figure Classification Test	Induction
4.	Surface Development Test	Visualization
5.	Recipe	Scheme of proportionality
6.	Mr. Tall-Mr. Short	Scheme of proportionality
7.	PLT	Propositional logic
8.	Genetics Test	Concepts of genetics covered in a basic undergraduate genetics course

A score based on rights only was obtained for tests 1 through 4. Tasks 5 and 6 were scored as 0=failure and 1=success. A subject was considered successful if proportional calculations were used to solve these tasks. Test 7, the test of propositional logic, was broken down into four catagories (conjunction, conditional, biconditional, and disjunction) and each catagory was scored based on the number correct. The genetics test was composed of 21 items, one of which was not scored because it was considered to be ambiguous by both instructors and students. Each item was scored as 0=wrong and 1=right. Prior to its use, the test was reviewed by two genetics instructors, four college biology teachers, and a science consultant from Educational Testing Service in Princeton, New Jersey. They agreed that the test adequately measured genetics concepts presented in a basic undergraduate genetics course.

RESULTS

A factor analysis employing the option for pairwise deletion of missing data was performed on the individual scores obtained from tests and tasks 1 through 6, four scores obtained from the PLT, and 20 scores (one per item) from the genetics test. Subject information concerning sex, age, status (sophomore, junior, senior), and years of mathematics studied was also included in the analysis. A regression coefficient lower than 0.5000 was not considered a substantial loading for a factor, although there were coefficients of 0.4800 and 0.4900 in the data.

The results indicate that 23.1% of the variance is explained by factor 1, 13.9% by factor 2, 9.2% by factor 3, and 8.6% by factor 4. Beyond this, an additional factor would have accounted for approximately 7.5% of variance. The cummulative percent of variance accounted for by four factors was 54.9%. The eigen values for factors 1, 2, 3, and 4 were 8.55530, 5.14720, 3.41223, and 3.18175, in that order.

The variables having substantial loadings in factor 1 were scores on the Paper Folding Test, Figure Classification Test, Surface Development Test, the Mr. Tall-Mr. Short task, PLT-disjunction, and scores on five genetics items. These items were concerned with the following: a dihybrid cross, meiosis (from diploid cell to gametes), the Hardy-Weinberg theorem, the numerical relationship between peptide bonds and amino acids, and the numerical relationship between nitrogenous bases and the number of amino acids.

Factor 2 loadings involved only a group of items from the genetics test concerned with the following: the number of gamete genotypes, mitosis, meiosis (from gametes to diploid cell), calculating gene frequency, a trihybrid test cross, a pedigree, and the relationship between a DNA sequence and its complimentary mRNA sequence.

Years of mathematics, the score on the Recipe task, and the PLT-conjunction score loaded substantially in the third factor. The score on Hidden Patterns Test and scores on the map units items loaded substantially in factor 4.

DISCUSSION

The results indicate that visualization, induction, scheme of proportionality, inclusive disjunction, and certain genetics topics have something in common with each other (see Table 2). However, note that the relation between Paper Folding Test (visualization) and Mr. Tall-Mr. Short (proportionality scheme) is both strong and significant. There are very weak relations between Recipe (proportionality scheme) and visualization tests that are not significant. This finding deserves further investigation.

It is interesting to note that there were a group of genetics items that clustered by themselves under factor 2. The association between these items and the aforementioned measures of flexibility of closure, visualization, induction, proportionality, and propositional logic is weak or nil.

It was not surprising to see PLT-conjunction and Recipe task load under the same factor; the relation here is strong and significant. There is also a strong, significant relation between flexibility of closure and the items concerning map units.

CONCLUSION

Interpretation of the data is limited because the sample size was extremely small and the variables were either continuous or dichotomous. In order to obtain an unbiased interpretation, research statisticians at Educational Testing Service in Princeton, New Jersey were consulted. The results reported in this paper reflect their suggestions for interpretation.

The results of this study invite further exploration of the relations between logical and spatial reasoning and the understanding of genetics concepts. Future research will include adjustments on the current measure of genetics concepts and additional measures of spatial and logical reasoning will be included while others deleted.

TABLE 2

CORRELATION COEFFICIENTS, PROBABILITIES, AND SIGNIFICANCE

Variables	Hidden Figures	Paper Folding	Figure Classification	Surface Development	Recipe	Mr. Tall-Mr. Short	Disjunction
Hidden Figures							
Paper Folding							
Figure Classification							
Surface Development	.65 (B) p=.001	.84 (A) p=.000					
Recipe							
Mr. Tall-Mr. Short		.73 (A) p=.000	.51 (C) p=.009	.56 (B) p=.004			
Conjunction					.70 (A) p=.000		
Conditional							
Biconditional							
Disjunction		.58 (B) p=.003	.60 (B) p=.002	.61 (B) p=.002		.64 (B) p=.001	
Problems:							
Dihybrid Cross						.59 (B) p=.002	.58 (B) p=.003
Hardy-Weinberg Calculation		.54 (B) p=.006	.58 (B) p=.003			.64 (B) p=.001	.73 (A) p=.000
Map Units-Calculation	.63 (B) p=.001			.64 (B) p=.001			
Peptide Bonds-Calculation		.62 (B) p=.002		.53 (C) p=.008		.73(A) p=.000	.60 (B) p=.002
Number of Amino Acids						.57(B) p=.004	

(A) significant at 0.001; two tailed test
(B) significant at 0.01; two tailed test
(C) significant at 0.02; two tailed test

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